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Potential development of bioethanol production in Vojvodina

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ABSTRACT

The Autonomous Province of Vojvodina is an Autonomous Province in Serbia, containing about 27% of its total population according to the 2002 Census. Contribution of renewable energy sources in total energy consumption of Vojvodina contemporary amounts to less than 1%, apropos 280 GWh/year. By combining of methods of introduction of new and renewable sources, systematic application of methods for increasing of energetic efficacy, as well as of introduction of the new technologies, percentage of contribution of the non-conventional energy sources in Vojvodina could be increased to as much as 20%. This paper presents the potential of development of bioethanol production in Vojvodina. Production of bioethanol on small farms can be successfully applied for processing of only 30 kg of corn per day, with obtaining of crude ethanol in the so-called "brandy ladle" and use of lygnocellulosic agricultural wastes as an energy source. In a case of construction of a larger number of such plants, the only possible solution is seen in the principle of construction of the so-called "satellite plants", which will on small farm produce crude ethanol, with obtaining and consumption of stillage for animal feeding, and consumption of agricultural wastes as energetic fuels. If stillage is to be used as feed in wet feeding, it is estimated that, because of restrictions established by the magnitude of animal farm, the upper limit of capacity of such enterprises that process is at some 10–15 tons of corn per day, and production of 3000–3500 hL of absolute ethanol per day. In such a case, for animal feeding necessary is to have herd with 1300–1700 of milking cows or 5000–25,000 heads of sheep and/or pigs. Technological model of separate grain processing ad bioethanol production from dextrose hydrolysates of starch is interesting for countries possessing plants for bioethanol production from molasses and plants for cereals processing into starch and dextrose hydrolysates of starch.

Contents

1. Introduction

The Autonomous Province of Vojvodina is an Autonomous Province in Serbia, containing about 27% of its total population according to the 2002 Census. It is located in the northern part of the country, in the Pannonia plain. Vojvodina is an energy-deficient province. The indigenous reserves of oil and gas are limited and the country is heavily dependent on the import of oil. The oil import bill is a serious strain on the country's economy and has been deteriorating the balance of payment situation. The country has become increasingly more dependent on fossil fuels and its energy security hangs on the fragile supply of imported oil that is subject to disruptions and price volatility [1]. Contribution of renewable energy sources in total energy consumption of Vojvodina contemporary amounts to less than 1%, apropos 280 GWh/year [2]. By combining of methods of introduction of new and

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renewable sources, systematic application of methods for increasing of energetic efficacy, as well as of introduction of the new technologies, percentage of contribution of the non-conventional energy sources in Vojvodina could be increased to as much as 20% [3,4].

In Vojvodina is bioethanol for fuel purposes still not produced, although there exist indications of preparation for construction of plants for such purposes. Because of that, it is necessary that competent organs of the AP Vojvodina as soon as possible bring corresponding programs and plans that should define and regulate production of bioethanol as fuel in Vojvodina. Having in mind that we are situated in Europe, and that we are oriented onto entrance in the EU, it is probably that regulative, as well as stimulative measures ought to be similar to the already existing ones in EU in that region.

Taking into account our agricultural production, in Vojvodina as raw materials for bioethanol as fuel can primarily be foreseen sugar- (sugar beet) and starch-containing raw materials (corn, wheat surpluses, potato surpluses or waste potato), followed by specifically intended raw materials planted on the nonused soils (hybrid sorghum, Jerusalem artichoke—topinambour, triticale) [5]. According to the estimations, agricultural production of Vojvodina already in the prolonged series of years realizes yearly surplus of cereals amounting about 1 million tons (mainly corn, and after it, wheat) that could be used for production of bioethanol as fuel. Besides of that, it is estimated that in Vojvodina exist some 1000 km^2 of no cultivated soils which offer possibilities for planting of cultures intended for bioethanol production (sorghum, Jerusalem artichoke).

In order to realize an economical production of bioethanol from husbandry cultures, an unavoidable prerequisite is the complete utilization of al by-products, primarily of spent grains and slopes, with their basic application as feed. On the process economy significant effect has also the applied process technology, as well as microbial species and their adaptation on the process conditions. In that respect, modern processes that are much more efficient and energetically favorable in the phases of substrate pretreatment, fermentation and especially, distillation and dehydratation stages of ethanol production.

In pursuance with experiences and norms that are in charge in the EU, bioethanol that is to be applied admixtured with motor gasoline, has to fulfill the requirement that its maximal allowable water content is 3000 ppm [6–8]. Besides of that, bioethanol intended for fuel has to have high ethanol content and must be refined and denaturated. Connected with the defining of bioethanol that is to be used in Vojvodina as fuel, it is necessary to adjust the existing rules with corresponding European standards.

Demands for bioethanol as an addition into motor fuel, amounting to 5.75% in the year 2010 in Vojvodina will be about 80,000 tons. To this quantity of bioethanol ought to be added the needs of bioethanol in pharmaceutical and chemical industries, as well as for the manufacture of strong liquors.

This paper presents the potential of development of bioethanol production in Vojvodina.

2. Bioethanol production on small farms

Production of bioethanol on small farms can be successfully applied for processing of only 30 kg of corn per day, with obtaining of crude ethanol in the so-called "brandy ladle" and use of lygnocellulosic agricultural wastes as an energy source. Basic material balance of such a production of ethanol is shown in Fig. 1 [9].

If as one of strategic decisions for processing of starchy raw materials their processing on small farms is to be adopted, consumption of slopes, or of spent grains in so-called wet feeding of livestock appears as an imperative. In such a case, for example

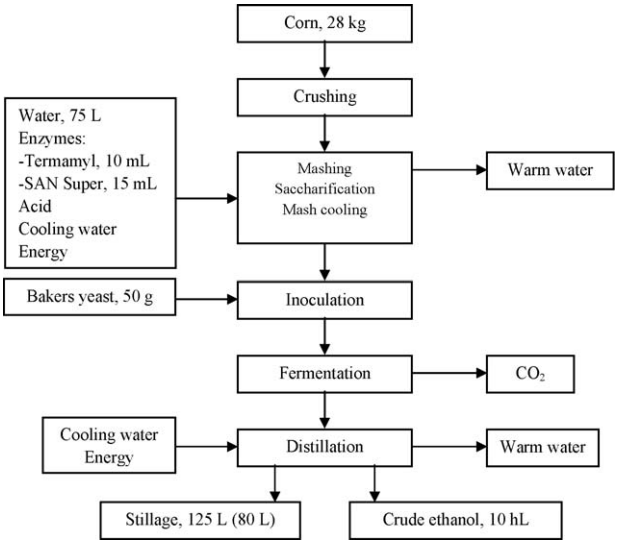

Fig. 1. Schematic presentation of material balance of bioethanol production on small farms.

defined in Fig. 1, minimal count of animals that should be permanently feeded in the stockyard amounts to 3–4 cattle animals, or about 20–30 pigs. In the case of something larger capacity, at processing of about 300 kg of corn per day and production of about 1000 L of stillage per day, it is already necessary to have crib for example, for fattening of 30 young bulls all around the year, with animals of different ages [9].

In a case of construction of a larger number of such plants, the only possible solution is seen in the principle of construction of the so-called "satellite plants", which will on small farm produce crude ethanol, with obtaining and consumption of stillage for animal feeding, and consumption of agricultural wastes as energetic fuels. So obtained crude bioethanol would be transported on rafination to central, modern equipped distillation-rectification unit (Fig. 2).

3. Bioethanol production on larger farms

If stillage is to be used as feed in wet feeding, it is estimated that, because of restrictions established by the magnitude of animal

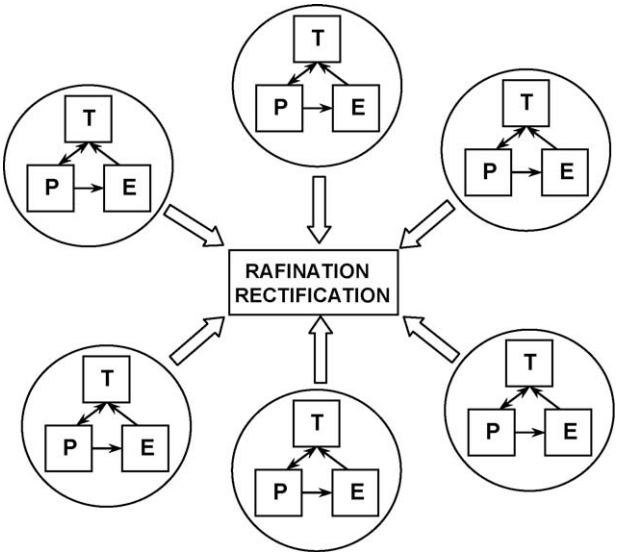

Fig. 2. Conceptional scheme of bioethanol production on small farms in Vojvodina, with rectification in common central processing unit (E: production of crude bioethanol; T: animal feeding; P: agricultural production).

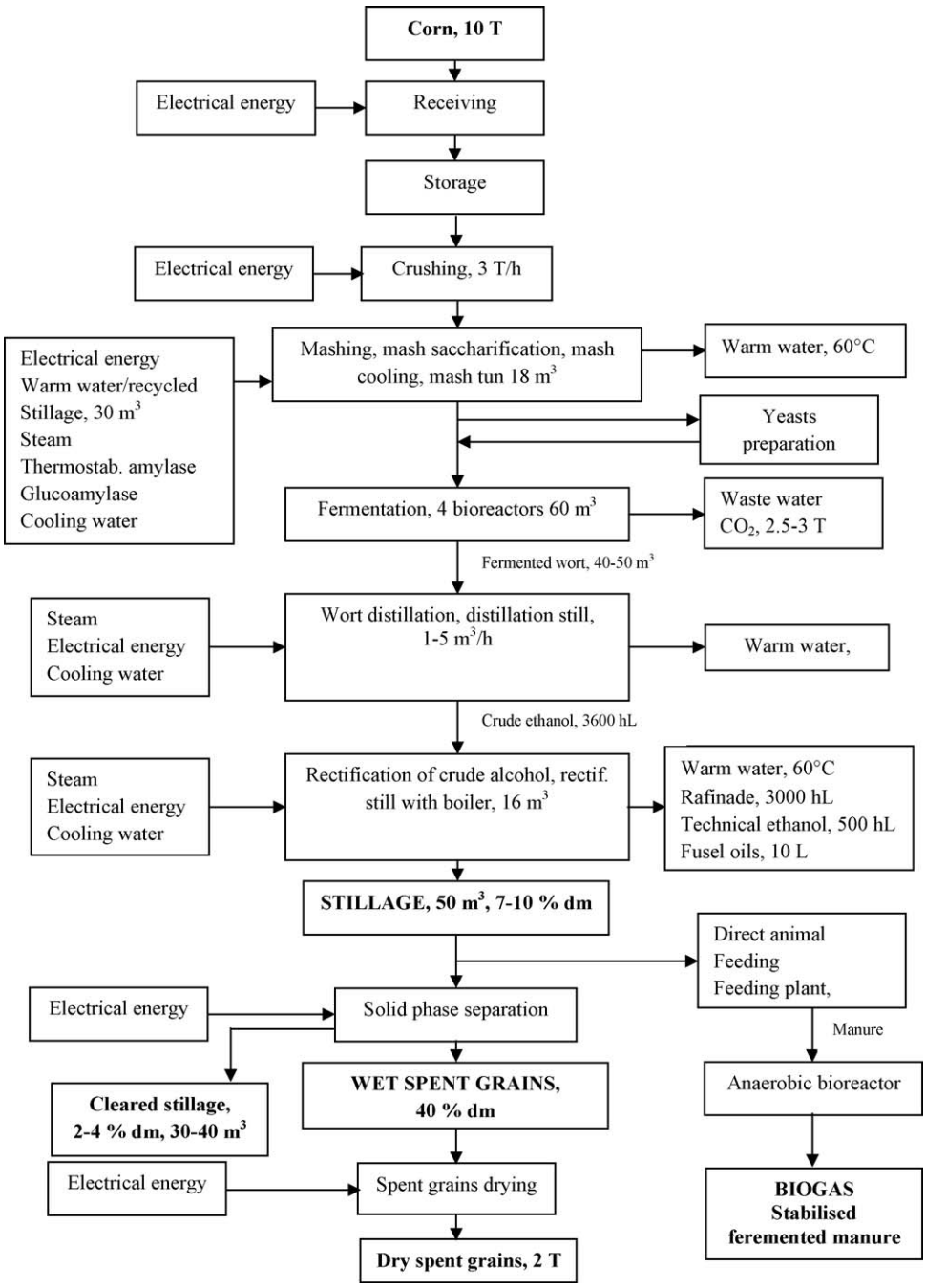

Fig. 3. Block scheme of technological process of processing of 10 tons of corn per day.

farm, the upper limit of capacity of such enterprises that process is at some 10–15 tons of corn per day, and production of 3000–3500 hL of absolute ethanol per day. Basic material balance of such production is outlined in Fig. 4. In such a case, for animal feeding necessary is to have herd with 1300–1700 of milking cows or 5000–25,000 heads of sheep and/or pigs [9].

In the case of working at small farms (Figs. 1 and 2), the obtained excrements supposingly, should not create any problems, because they could, using primitive process, be used as manure. In spite of that, more convenient solution, and for larger enterprises (Fig. 3) unavoidable solution, is their conversion by the anaerobic biotechnological conversion into the stabilized manure (bio-fertilizer) and biogas (energent). So obtained biogas could be applied for supplementing of energetic needs of ethanol factory, as well as of the farm itself.

Considerable effect of such an approach is oh ecological nature, because it solves questions of waste water streams of the ethanol factory, as well as question of waste waters and unpleasant smells of animal production, especially in the case of feeding of pigs. Without performing broader analyze, it is clear that construction of plant for bioethanol production on larger farms represents serious investitional action, for which the principal disadvantage lies in the fact that, because of relatively small capacity, it is almost impossible to apply contemporary knowledges in domains of distillation and rectification, so that energetically extensive solutions, stemming from the beginning of the last century, have to be applied.

Taking in account facts that at construction of such enterprises with relatively large capacities, it is obvious to possess or to construct farm for stillage consumption by the wet feeding

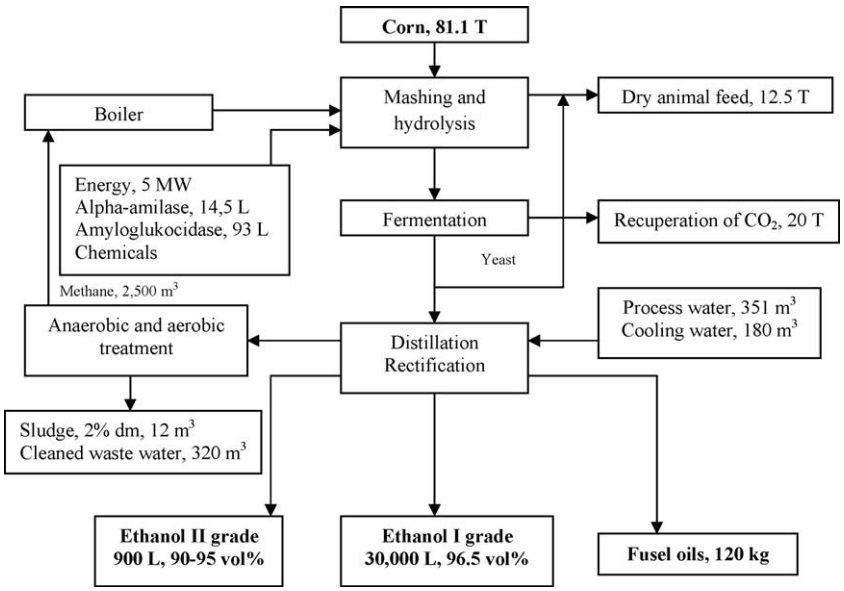

Fig. 4. Scheme of the conventional technological model of ethanol production from cereals with its material balance for a capacity of 30,000 hL/day.

process, and that problems of excrements must be solved, the value of the necessary investments significantly increase. Because of that, such a solution is recommended only for exceptional circumstances, when favorable conditions it permit, and preference is given to the abovementioned system of small plants with central rafination, or to construction of large, and even of huge (industrial) plants for processing of starchy raw materials into bioethanol.

4. Bioethanol production in industrial plants

Conventional technological model for production of ethanol from cereals is outlined in Fig. 4. According to this model, production is accomplished by application of high temperatures and pressures for pretreatment of cereals, or by application of the "cold process", which is, undoubtedly, more rational. In this process, problem of stillage and of waste water is solved by application of anaerobic/aerobic process of treatment (such as the "Anamet" process), what is useful from environment protection point of view, but not at the same time from the point of view of rational application of stillage as animal feed. Positive aspect of this solution, in comparation with the classical one, where stillage was discarded without any treatment into environment, is utilization of energy of the produced biogas from anaerobic treatment, followed by production of biological fertilizer (biological sludge that is obtained during anaerobic treatment), and environment protection. Disadvantage of this solution is irrational utilization of raw materials and losses created because of that, which are not compensated with the production of biogas and of biological fertilizer [9].

Technological model of the complex processing of cereals into bioethanol and concomitant products (Fig. 5), doubtless, is the most complex, and at the same time, the most rational solution for ethanol production from cereals, as it incorporates all modern scientific knowledges in the production, and ethanol prices makes competitive with prices of gasoline fuels and of oil as chemical raw material. It is enabled, besides to complete utilization of raw materials, with significant energetic savings, what demonstrate data shown in Table 1.

As it follows from this scheme, corn is firstly degerminated and deglutenated, with the obtaining of products that are very valuable and which have high demands on the world market. Starch milk that is obtained by milling (smaller grains) is processed into high fructose syrup which is very demandable as sweetener on the world market, so that its production has trend of high expansion. Starch milk containing larger particles, broken corn and bran are sent to saccharification. Saccharified mass is separated from solid residues and transported to fermentation, and after that to distillation and rectification. The separated (nonsaccharified) part of kernel is blended with stillage and through evaporation and drying processes converted into animal feed. In this production waster streams are absent, so that the total utilization of raw materials reaches values of 99%.

Just described technological model of complex processing of cereals is the most perspective one and it should serve as a basis for future development of this production. The newest investments in the world confirm this. Only Vogelbusch Company from Wien constructed in the USA several plants for complex processing of corn into bioethanol, each of which with the capacity of 50 million liters per day.

Technological model of separate grain processing ad bioethanol production from dextrose hydrolysates of starch is interesting for countries possessing plants for bioethanol production from molasses and plants for cereals processing into starch and dextrose hydrolysates of starch. Such situation is in Vojvodina. Simplified scheme of this model is outlined in Fig. 6.

On Fig. 6 is arbitrary given degree of processing of cereals in the so-called starch producing factory. However, in every case, starch factory produces dextrose containing hydrolysate of starch having higher DE values (more than 80), hydrol and corn steep liquor (CSL), which are, mixed in the established ratios, transferred into bioethanol producing plant.

For bioethanol production can be applied already existing plants for bioethanol production from molasses, or newly constructed plants.

Using such model of cereals processing and bioethanol production, as in the case of complex plants, high rationality of production is achieved, although not so high as in complex plants, which enable creation of completely closed material and energy streams.

Great benefit of such one model of cereals processing is based on the fact that by application of hydrol and of CSL

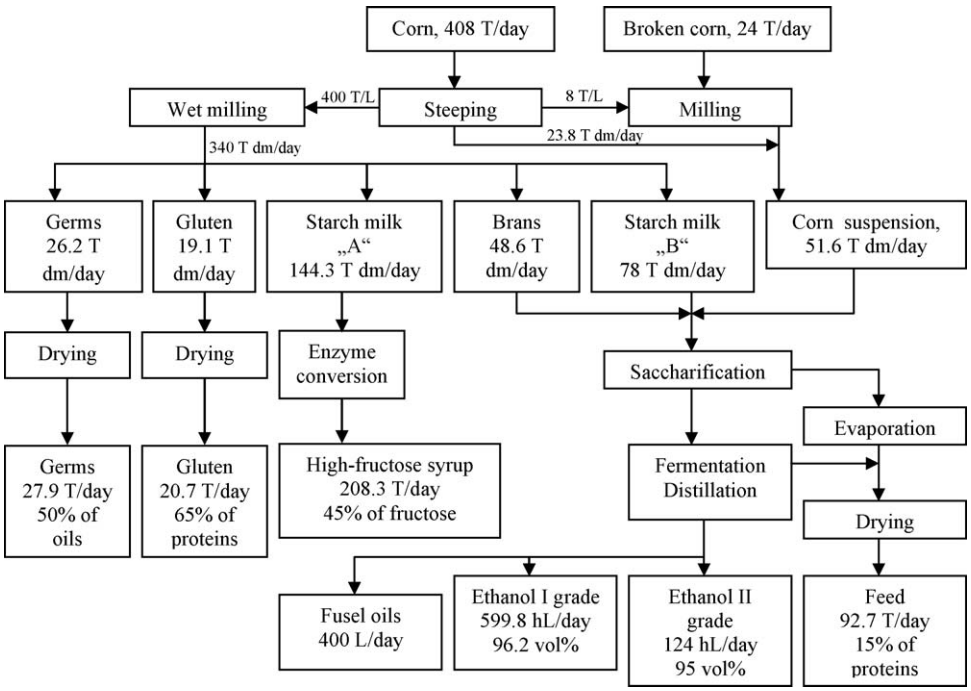

Fig. 5. Scheme of complex technological process of bioethanol production from corn with its material balance for a capacity of 30,000 hL/day.

which are by-products from processing of cereals, as well as with specified production of starchy dextrose hydrolysates with high DE values (above 80), considerable quantities of molasses can be freed for production of small-scale valuable products, such as organic acids, vitamins, antibiotics, fine chemicals etc. That strongly contributes to development of biotechnology, which is considered to be one of the most prospective industrial branches in Vojvodina.

Table 1
Overview of energy consumption in conventional and in contemporary processes of bioethanol production from cereal raw materials.

Production phase	MJ/L	
	Conventional process	Modern process
Pretreatment of raw materials	0.1	0.1
Saccharification	8.0	0.7
Fermentation	0.06	0.06
Distillation to the absolute bioethanol	10.9	5.8
Evaporation and drying of stillage	10.9	8.1

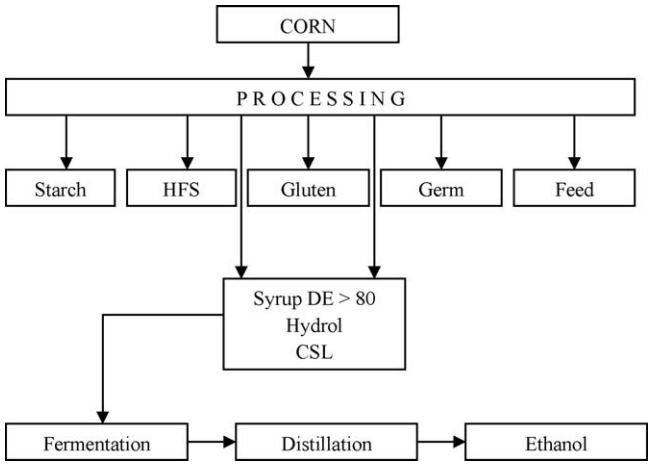

Fig. 6. Simplified scheme of technological model of the separate processing of cereals and production of bioethanol from dextrose starch hydrolysates.

5. Conclusion

Analyzing the existing capacities and equipment for production of bioethanol in Vojvodina, it is possibly to conclude that the existing equipment and capacities can not satisfy needs for bioethanol production for fuel. With reconstruction and modernization of the existing plants, especially in domains of raw materials processing and bioethanol dehydratation, they could be reconditioned for production of a part of bioethanol for fuel. Nevertheless, the capacities would be insufficient for fulfilling of needs of ethanol as a supplement into motor fuels, so that there exist the need for construction of new capacities. Pursuant to that, several concepts could be discussed; one of them is the construction of larger plants, or construction of so-called "satellite" plants), for production of crude ethanol on small farms, with the obtaining and consumption of spent grains (for livestock feeding), using at the same time agricultural wastes as supplies of energy for these plants. The so obtained crude bioethanol is supposed to be transferred on rafination into central, contemporary equipped distillation–rectification installation.

Acknowledgment

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